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SENSITIVITY ANALYSIS OF PRODUCTION AND POWER CONSUMPTION USING A COMPUTER BASED BUCKET WHEEL EXCAVATOR-CONVEYOR-BIN MODEL

J.K. Szymanski

December, 1986

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by

J.K. SZYMANSKI*

ABSTRACT

The following report analyzes the sensitivity of production and power consumption to various operating parameters using the controllable simulation model of the bucket wheel excavator-conveyor-bin system. This interactive computer simulation model of BWE-conveyor-bin-network has been developed by the National Research Council and Canstar Oil Sands Ltd.

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ÉTUDE DE LA PRODUCTION ET DE LA CONSOMMATION D'ÉNERGIE À L'AIDE D'UN MODÈLE AUTOMATISÉ D'EXCAVATION À GODETS-CONVOYEUR-SILO

par

J.K. Szymanski*

RÉSUMÉ

Le présent rapport analyse de susceptibilité de la production et de la consommation d'énergie par rapport à divers paramètres d'opération à l'aide d'un modèle de simulation contrôlable d'un système d'excavation à godets-convoyeur-silo. Ce modèle de simulation automatisé interactif du réseau d'excavation à godets-convoyeur-silo a été mis au point par le Conseil national de recherches du Canada et la Canstar Oil Sands Ltd.

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INTRODUCTION

This report describes applications experiments carried by the author using the model. The object of these requirements was a sensitivity analysis of production and power consumption to various operating factors of the interactive bucket wheel excavator-conveyor-bin model.

The interactive simulation model of conveyor systems was jointly developed by NRC and Project 80 to be used by Canstar Ltd. at their proposed oil sands mine (1). The bucket wheel excavator model has abeen developed as either a stand alone model or as a model attached to other equipment such as a conveyor belt. The stand alone models for the bucket wheel excavator and conveyor belts were interfaced together on a VAX-11/180 computer by NRC in 1982. CANMET issued contract 23440-5-9249/01SQ in order to assess the applicability of the simulation model to general industry needs, namely, a simulator that will assist with the selection of equipment and improved operating methods. The final report for the above project was completed by Monenco Consultants Limited on September 19, 1986 (3). It was concluded that the NRC/CANMET simulator is not yet ready to fulfill the requirements of the mining industry.

OPERATION OF BUCKET WHEEL EXCAVATOR-CONVEYOR-BIN MODEL

The test case is derived from Pit 04 at the Highvale Mine (3). This Monenco case study relates to an east-west mining sequence in Pit 04. The bucket wheel excavator was used to prestrip overburden in advance of an Marion-8750 dragline. The dragline is to remove the lowermost 22 meters of overburden, leaving the remainder to be handled by the bucket wheel excavator. The BWE to be used in the Monenco case study is a larage Model 1900 bucket wheel excavator. The machine has a 13m wheel diameter, has an expected output of 2700 bcm per operating hour, and can cut a single bench up to 30m high. The test case represents the initial position shown in Figure 1.

For this experiment CONVEY.DAT file was edited to increase the time at which a conveyor must run empty before warning the operator to 1000 minuts. The bin outflow rate has been changed to 2250Lcm/hr in BIN.DAT

file. The conveyor more time in ATRIB.DAT file has been set to 8 hours and maximum time between BWE mechanical breakdowns in DIST.DAT file was increased to 3840 minuts.

EXPERIMENT 1

Three runs were performed for a length of three shifts to compare the productivity of lateral, bench cut, drop cut and drop and bench cut combined.

RESULT:

These runs indicate that drop cutting is only 70% as efficient as bench cutting. The reasons for this difference relate to the emprical equations used in the model. For the execution of the bench and drop cut combined method the program halted and displayed the following error message: IMPOSSIBLE BOOM LENGTH IS LONGER THAN BLOCK.

EXPERIMENT 2 (Relationship between operator efficiency and productivity).

The operator efficiency was changed from 0.5 to 1.0 in increments of 0.1 (file atrib.dat). The simulation was then run for 3 shifts with a bench cut.

RESULT:

The production increased as the operator efficiency increased. (Fig. 2).

EXPERIMENT 3 (Power consumption as a function of time).

Runs of three shifts were performed with the Monenco 1 experiment 46 data for lateral, bench, and drop cuts giving reports every shift.

RESULT:

The power consumption was the same for each shift. (Fig. 3).

EXPERIMENT 4 (The effect of boulder delay time on production).

The statistics of the boulder delay (file dist.dat) were changed from mean of 1.0 standard deviation of 0.01 minimum and maximum of 0.9 and 1.1 respectively to means of 2.0, 5.0 and 10.0 minutes the standard deviation was kept constant as was the range above and below the mean.

RESULT:

The productivity of the BWE remained constant over all values for boulder delay time (Fig. 4).

EXPERIMENT 5 (The effect of maximum digging resistance on production and energy ratio).

The maximum digging resistance was changed from 6.0 to 20.0 kg/sq.cm in increments of 2.0 kg/sq.cm (file atrib.dat).

RESULT:

Surprisingly the production increased as maximum digging resistance increased and the energy ratio decreased (Figs. 5 and 6). Received error message when digging resistance was set at 6.0 kg/sq.cm.

ONE OF THE BLOCKS FOR BENCH #1
SEC #1 LAY #1 COL #1
HAS A SLICE TIME OF 0--IMPOSSIBLE
TOP CUT TIME = -13.62 MINS
BENCH CUT TIME = -13.62 MINS
CUT TYPE # = 3

FIG. 1 Configuration of BWE-conveyor bin model.

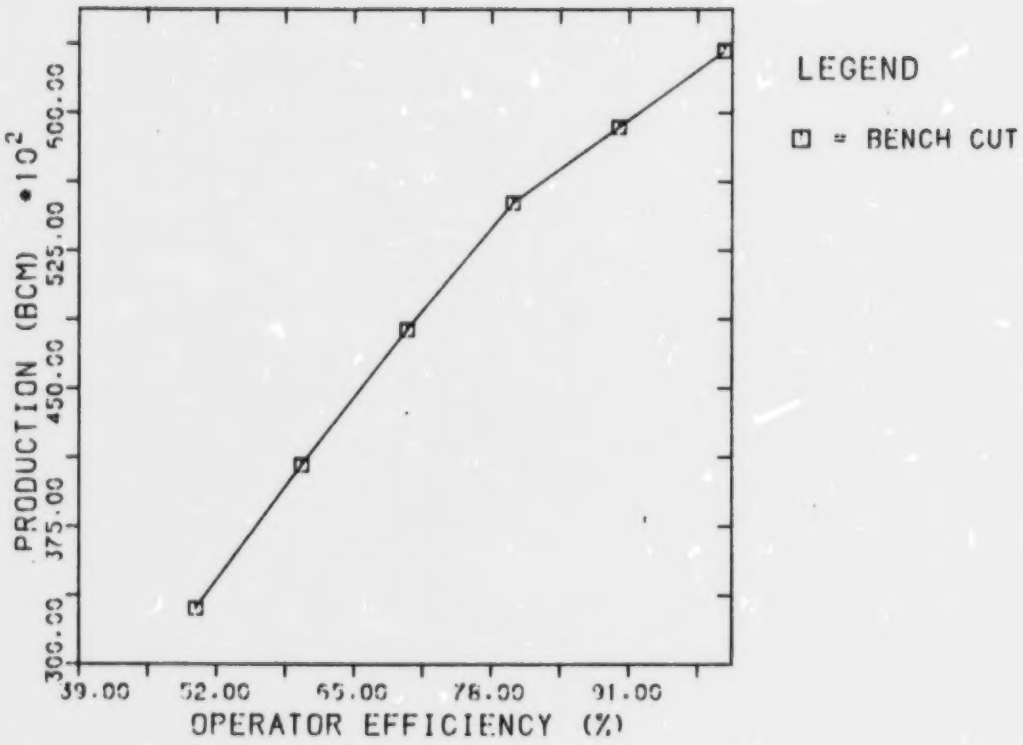

Fig 2. Efficiency vs. production

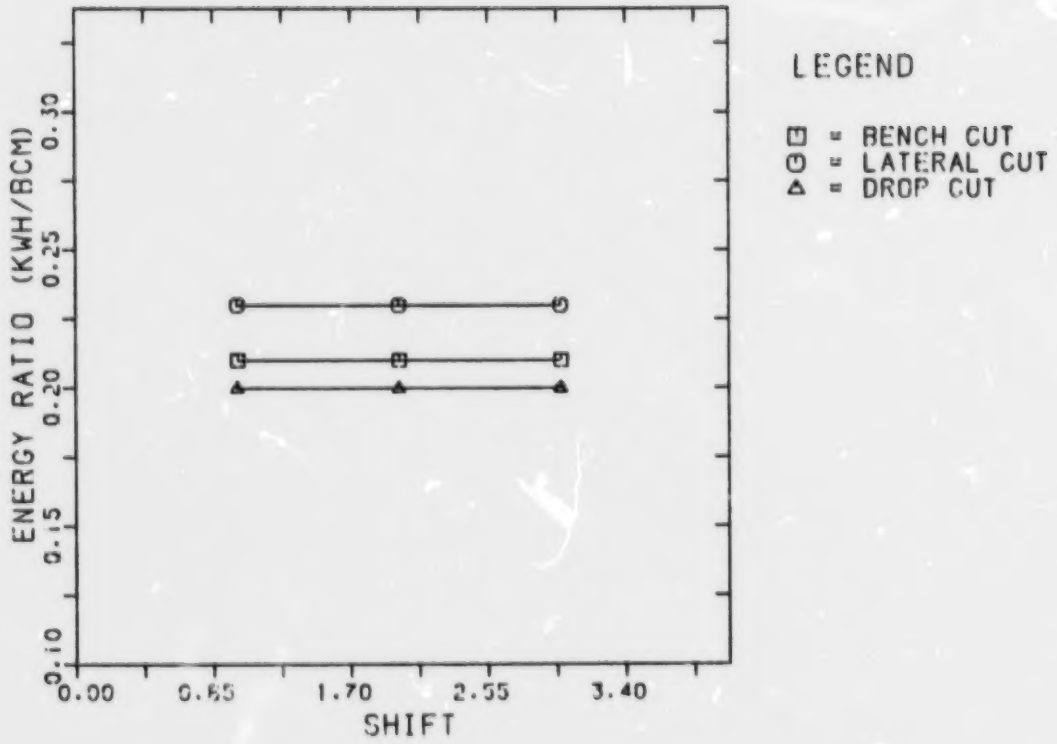

Fig 3. Energy consumption vs time

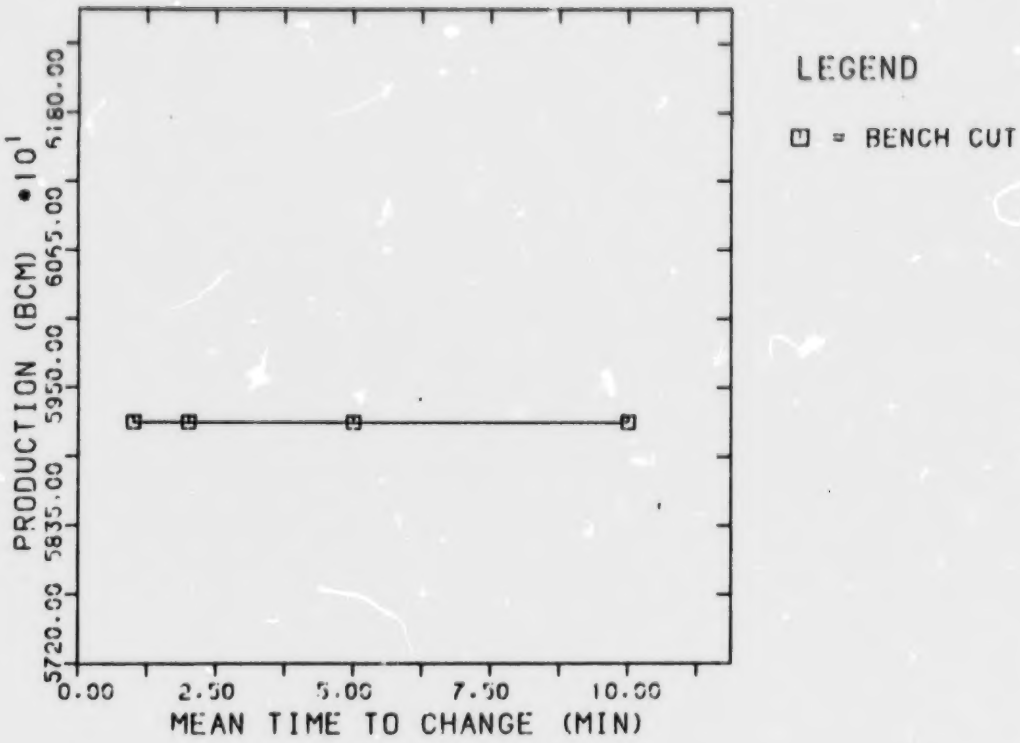

Fig 4. Bolder Delay vs. production

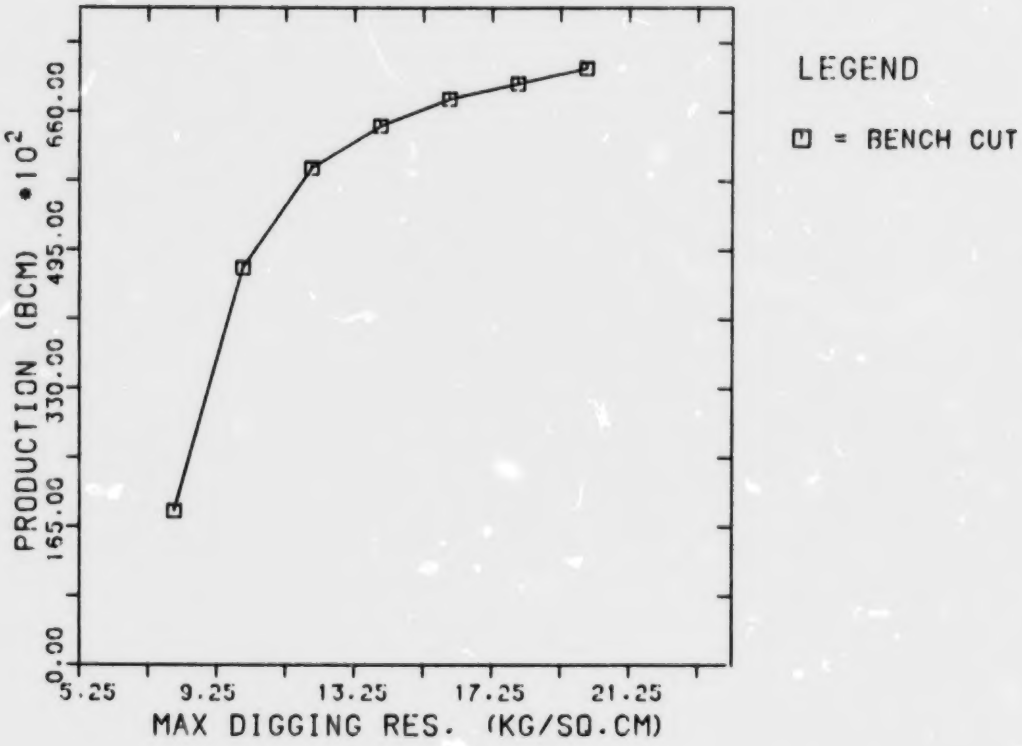

Fig 5. Resistance vs. production

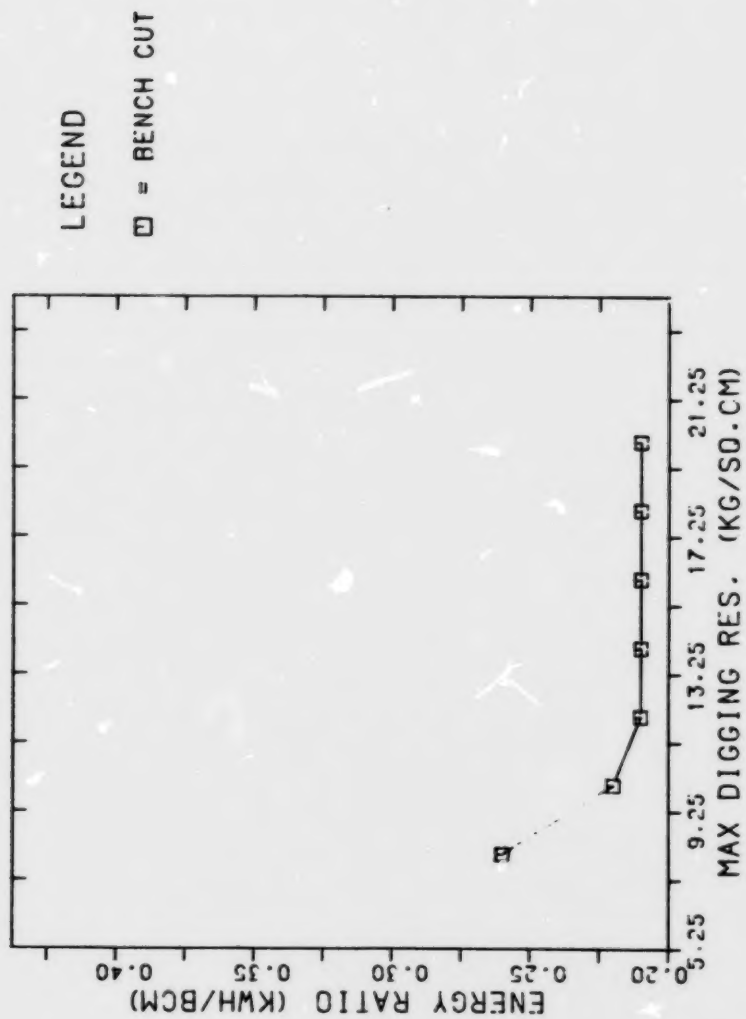

Fig 6. Resistance vs. energy ratio

CONCLUSIONS

1. The productivities that the model predicts for different cut methods indicate that drop cutting is only 70% as efficient as bench cutting. The reasons for this significant difference relate to the empirical equations used in the model.

2. In general, the sensitivity experiments performed indicated that the trend of obtained functions by the simulator is in agreement with the expected behaviour. Only in experiment 5 the observed increase in production with increase in digging resistance was opposite to that expected.

3. The echo of the input parameters in the output report and the time history file is very useful.

RECOMMENDATIONS

Replace emprical formulae in BWE module in order to represent the following activities:

- time to complete a slice,
- reverse slew time
- tramming time.

this may be done by using specified distribution functions associated with the random sampling functions.

REFERENCES

1. Chan, A.W. "An interactive simulation model of conveyor systems in tar sand mining". System model report LTR-CS-227, 1982; NRC.

2. Gibb, G.E. "Interactive model of an open-pit mine bucket wheel excavator model. Canstar Oil Sand LTD, Report 1150.

3. Monenco Consultants Limited "The Assessment evaluation and validation of a computer based simulation model"; DSS Contract Report 8291-8/3978, 1986.

APPENDIX A

OPERATION OF BWE-CONVEYOR-BIN-MODEL; PRINT OF EXPERIMENTS RUN.

EXPERIMENT 1 BENCH CUT

CONVEYOR NETWORK REPORT (TOTAL) AT TIME 8: 0

SECT NO.	STAT CODE	MATL CODE	PR.RAT BCM/HR	CYCLE(NO DEL) MIN (MIN)	WORK MIN	IDLE MIN	DOWN MIN	ENERGY CONS KWH/BCM	PRODUC. BCM
1	2	2	1646	12.(12.)	1379	0	0	0.65	58644
2	2	2	1646	5.(5.)	1377	0	0	0.42	58639
3	2	2	1646	4.(4.)	1377	0	0	0.36	58643

CONVEYOR UTILIZATION REPORT AT TIME 8: 0

RUNNING:

SECTION NO.	LOADED MIN	%	EMPTY MIN	%
1	1229	89.1	150	10.9
2	1215	88.2	162	11.8
3	1214	88.1	163	11.9

DELAYS:

SECTION NO.	WAITING MIN	%	RELOCATION MIN	%	ROLLERS MIN	%	TRIPPING MIN	%	SWITCHOVER MIN	%	REVERSE MIN	%
1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

BELT OVERLOADS:

SECTION NO.	FREQUENCY	CUMUL.EXCESS BCM/HR
1	0	0
2	0	0
3	0	0

CONVEYOR PERFORMANCE INDICATORS

SECTION NO.	MECH.AVAIL %	DEMAND %	UTILIZ %	OP.EFF %
1	100.00	100.00	95.81	100.00
2	100.00	100.00	95.63	100.00
3	100.00	100.00	95.67	100.00
AVE	100.00	100.00	95.71	100.00

*** TOTAL REPORT ***

*** PRODUCTION SUMMARY ***

BWE # ERGY RATIO	DIG.RATE(ORE) VOL.PROD BCM./HR	DIG.RATE(WA) VOL.PROD BCM./HR	PRODUCT COST/BCM. BCM./HR	ACC.ENER	ACC.ENER	EN
KWH/BCM.	ORE(BCM.)	WA(BCM.)	$	ORE(KWH)	WA(KWH)	
1900	2903.7	0.0	2775.9	12581.1	0.0	
0.21	59211.0	0.0	0.14			
TOT/AVE	2903.7	0.0	2775.9	12581.1	0.0	
0.21	59211.0	0.0	0.14			

*** PERFORMANCE INDICATORS **

*

BWE # MAINT.EFF	MECH.AVAIL REPAIR RATIO		DEMAND	UTIL	OP.EFF
	%		%	%	%
1900	88.88		100.00	88.88	95.60
	----	----			
AVE	88.88		100.00	88.88	95.60
	----	----			

*** TIME STATISTICS ***

BWE # OTHER DELAYS	DIGGING ORE(HRS)	DIGGING BREAKDOWN WA(HRS)	DIGGING IDLE	BOULD. DELAY	BOULD. DELAY
(HRS)	TIME(HRS)		(HRS)	ORE(HRS)	WASTE(HRS)
1900	20.39	0.00		0.00	0.00
0.94	2.67	0.00			
TOTAL	20.39	0.00		0.00	0.00
0.94	2.67	0.00			

```
** C A N S T A R  S I M U L A T I O N  R U N **
     DATE:   27-OCT-86   TIME:   15:04:12

**** BWE NO.1900 ***DIGGING SLICE TIME        ***

                        0   15   30   45   60   75   90  105  120  135  150
                        +    +    +    +    +    +    +    +    +    +    +

ZERO TO            1.00000*
                   1.30000*
                   1.60000*
                   1.90000*
                   2.20000*
                   2.50000*
                   2.80000*
                   3.10000*
                   3.40000*
                   3.70000*
                   4.00000*
                   4.30000*
                   4.60000*
                   4.90000*
                   5.20000*
                   5.50000*
                   5.80000*
                   6.10000*
                   6.40000*
                   6.70000*
                   7.00000*
GREATER THAN       7.00000**********************************************
                        +    +    +    +    +    +    +    +    +    +    +
```

** C A N S T A R S I M U L A T I O N R U N **
DATE: 27-OCT-86 TIME: 15:04:12

**** BWE NO.1900 ***TRAMMING TO SLICE: TIME ***

```
                        0   15   30   45   60   75   90  105  120  135  150
                        +    +    +    +    +    +    +    +    +    +    +
ZERO TO           1.00000****************************************
                  1.30000*
                  1.60000*
                  1.90000*****
                  2.20000*
                  2.50000*
                  2.80000*
                  3.10000*
                  3.40000*
                  3.70000*
                  4.00000*
                  4.30000*
                  4.60000*
                  4.90000*
                  5.20000*
                  5.50000*
                  5.80000*
                  6.10000*
                  6.40000*
                  6.70000*
                  7.00000*
GREATER THAN      7.00000*
                        +    +    +    +    +    +    +    +    +    +    +
```

EXPERIMENT 1 DROP CUT

CONVEYOR NETWORK REPORT (TOTAL) AT TIME 8: 0

SECT NO.	STAT CODE	MATL CODE	PR.RAT BCM/HR	CYCLE(NO DEL) MIN (MIN)	WORK MIN	IDLE MIN	DOWN MIN	ENERGY CONS KWH/BCM	PRODUC. BCM
1	2	2	1985	12.(12.)	1379	0	0	0.72	41494
2	2	2	0	5.(5.)	1379	0	0	0.44	41494
3	2	2	1985	4.(4.)	1379	0	0	0.37	41218

CONVEYOR UTILIZATION REPORT AT TIME 8: 0

RUNNING:

SECTION NO.	LOADED MIN	%	EMPTY MIN	%
1	1229	89.1	150	10.9
2	1217	88.3	161	11.7
3	1216	88.1	163	11.9

DELAYS:

SECTION NO.	WAITING MIN	%	RELOCATION MIN	%	ROLLERS MIN	%	TRIPPING MIN	%	SWITCHOVER MIN	%	REVERSE MIN	%
1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

BELT OVERLOADS:

SECTION NO.	FREQUENCY	CUMUL.EXCESS BCM/HR
1	0	0
2	0	0
3	0	0

CONVEYOR PERFORMANCE INDICATORS

SECTION NO.	MECH.AVAIL %	DEMAND %	UTILIZ %	OP.EFF %
1	100.00	100.00	95.81	100.00
2	100.00	100.00	95.81	100.00
3	100.00	100.00	95.81	100.00
AVE	100.00	100.00	95.81	100.00

*** TOTAL REPORT ***

*** PRODUCTION SUMMARY ***

BWE # ENERGY RATIO KWH/BCM.	DIG.RATE(ORE) VOL.PROD BCM./HR ORE(BCM.)	DIG.RATE(WA) VOL.PROD BCM./HR WA(BCM.)	PRODUCT COST/BCM. BCM./HR $	ACC.ENER ORE(KWH)	ACC.ENER WA(KWH)	EN
1900	1995.4	0.0	1963.3	8450.2	0.0	
0.20	41877.0	0.0	0.20			
TOT/AVE	1995.4	0.0	1963.3	8450.2	0.0	
0.20	41877.0	0.0	0.20			

*** PERFORMANCE INDICATORS **

BWE # MAINT.EFF %	MECH.AVAIL REPAIR RATIO %	DEMAND %	UTIL %	OP.EFF %
1900	88.88	100.00	88.88	98.39
AVE	88.88	100.00	88.88	98.39

*** TIME STATISTICS ***

BWE # OTHER DELAYS (HRS)	DIGGING BREAKDOWN ORE(HRS) TIME(HRS)	DIGGING IDLE WA(HRS) (HRS)	BOULD. DELAY ORE(HRS)	BOULD. DELAY WASTE(HRS)
1900	20.99	0.00	0.00	0.00
0.34	2.67	0.00		
TOTAL	20.99	0.00	0.00	0.00
0.34	2.67	0.00		

** C A N S T A R S I M U L A T I O N R U N **
DATE: 27-OCT-86 TIME: 15:06:09

**** BWE NO.1900 ***DIGGING SLICE TIME ***

```
                        0   15   30   45   60   75   90  105  120  135  150
                        +    +    +    +    +    +    +    +    +    +    +
ZERO TO          1.00000*
                 1.30000*
                 1.60000*
                 1.90000*
                 2.20000*
                 2.50000*
                 2.80000*
                 3.10000*
                 3.40000*
                 3.70000*
                 4.00000*
                 4.30000*
                 4.60000*
                 4.90000*
                 5.20000*
                 5.50000*
                 5.80000*
                 6.10000*
                 6.40000*
                 6.70000*
                 7.00000*
GREATER THAN     7.00000**************************************************
                        +    +    +    +    +    +    +    +    +    +    +
```

** C A N S T A R S I M U L A T I O N R U N **
DATE: 27-OCT-86 TIME: 15:06:09

**** BWE NO.1900 ***TRAMMING TO SLICE: TIME ***

```
                      0   15   30   45   60   75   90  105  120  135  150
                      +    +    +    +    +    +    +    +    +    +    +
ZERO TO         1.00000**************************************************
                1.30000*
                1.60000*
                1.90000*
                2.20000*
                2.50000*
                2.80000*
                3.10000*
                3.40000*
                3.70000*
                4.00000*
                4.30000*
                4.60000*
                4.90000*
                5.20000*
                5.50000*
                5.80000*
                6.10000*
                6.40000*
                6.70000*
                7.00000*
GREATER THAN    7.00000*
                      +    +    +    +    +    +    +    +    +    +    +
```

** C A N S T A R S I M U L A T I O N R U N **
DATE: 27-OCT-86 TIME: 15:06:09

**** BWE NO.1900 ***BOULDER DELAY TIME ***

```
                        0    5   10   15   20   25   30   35   40   45   50
                        +    +    +    +    +    +    +    +    +    +    +
ZERO TO          0.01000**
                 0.07000*
                 0.13000*
                 0.19000*
                 0.25000*
                 0.31000*
                 0.37000*
                 0.43000*
                 0.49000*
                 0.55000*
                 0.61000*
                 0.67000*
                 0.73000*
                 0.79000*
                 0.85000*
                 0.91000*
                 0.97000*
                 1.03000*
                 1.09000*
                 1.15000*
                 1.21000*
GREATER THAN     1.21000*
                        +    +    +    +    +    +    +    +    +    +    +
```

EXPERIMENT 1 DROP CUT

CONVEYOR NETWORK REPORT (TOTAL) AT TIME 8: 0

SECT NO.	STAT CODE	MATL CODE	PR.RAT BCM/HR	CYCLE(NO DEL) MIN (MIN)	WORK MIN	IDLE MIN	DOWN MIN	ENERGY CONS KWH/BCM	PRODUC. BCM
1	2	2	1646	12.(12.)	1379	0	0	0.77	34413
2	2	2	1646	5.(5.)	1379	0	0	0.47	34421
3	2	2	1646	4.(4.)	1379	0	0	0.39	33961

CONVEYOR UTILIZATION REPORT AT TIME 8: 0

RUNNING:

SECTION NO.	LOADED MIN	%	EMPTY MIN	%
1	1229	89.1	150	10.9
2	1217	88.3	162	11.7
3	1215	88.1	163	11.9

DELAYS:

SECTION NO.	WAITING MIN	%	RELOCATION MIN	%	ROLLERS MIN	%	TRIPPING MIN	%	SWITCHOVER MIN	%	REVERSE MIN	%
1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

BELT OVERLOADS:

SECTION NO.	FREQUENCY	CUMUL.EXCESS BCM/HR
1	0	0
2	0	0
3	0	0

CONVEYOR PERFORMANCE INDICATORS

SECTION NO.	MECH.AVAIL %	DEMAND %	UTILIZ %	OP.EFF %
1	100.00	100.00	95.81	100.00
2	100.00	100.00	95.81	100.00
3	100.00	100.00	95.80	100.00
AVE	100.00	100.00	95.81	100.00

*** TOTAL REPORT ***

*** PRODUCTION SUMMARY ***

BWE # ERGY RATIO	DIG.RATE(ORE) VOL.PROD BCM./HR	DIG.RATE(WA) VOL.PROD BCM./HR	PRODUCT COST/BCM. BCM./HR	ACC.ENER	ACC.ENER	EN
KWH/BCM.	ORE(BCM.)	WA(BCM.)	$	ORE(KWH)	WA(KWH)	
1900	1659.7	0.0	1635.4	7938.0	0.0	
0.23	34884.0	0.0	0.24			
TOT/AVE	1659.7	0.0	1635.4	7938.0	0.0	
0.23	34884.0	0.0	0.24			

*** PERFORMANCE INDICATORS **

BWE # MAINT.EFF	MECH.AVAIL REPAIR RATIO	DEMAND	UTIL	OP.EFF
%	%	%	%	%
1900	88.88	100.00	88.88	98.53
AVE	88.88	100.00	88.88	98.53

*** TIME STATISTICS ***

BWE # OTHER DELAYS	DIGGING BREAKDOWN ORE(HRS)	DIGGING BREAKDOWN WA(HRS)	DIGGING IDLE	BOULD. DELAY	BOULD. DELAY
(HRS)	TIME(HRS)	TIME(HRS)	(HRS)	ORE(HRS)	WASTE(HRS)
1900	21.02	0.00	0.00	0.00	0.00
0.31	2.67	0.00			
TOTAL	21.02	0.00	0.00	0.00	0.00
0.31	2.67	0.00			

** C A N S T A R S I M U L A T I O N R U N **
DATE: 27-OCT-86 TIME: 15:02:16

**** BWE NO.1900 ***DIGGING SLICE TIME ***

```
                        0   10   20   30   40   50   60   70   80   90  100
                        +    +    +    +    +    +    +    +    +    +    +
ZERO TO          1.00000*
                 1.30000*
                 1.60000*
                 1.90000*
                 2.20000*
                 2.50000*
                 2.80000*
                 3.10000*
                 3.40000*
                 3.70000*
                 4.00000*
                 4.30000*
                 4.60000*
                 4.90000*
                 5.20000*
                 5.50000*
                 5.80000*
                 6.10000*
                 6.40000*
                 6.70000*
                 7.00000*
GREATER THAN     7.00000**********************************************
                        +    +    +    +    +    +    +    +    +    +    +
```